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Abstract

ON THE STABILITY OF STEAM-COOLED FAST REACTORS WITH CERAMIC FUEL

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By virtue of their short generation times fast reactors may be considered as particularly safe, provided that their reactivity feedback is governed by a prompt negative contribution from effects inherent to the system. In large ceramic fueled reactors this is to be ensured by the Doppler coefficient of reactivity. It is generally known that stability may be jeopardized by sufficiently large delayed contributions of either sign to the total reactivity feedback. Nevertheless one has to cope with the fact that Uranium-Plutonium oxide fueled fast breeder reactors with core volumes larger than a few hundred liters exhibit sizable positive void coefficients if they are cooled by steam. The present paper derives stability criteria which allow to determine the maximum permissible ratio of magnitudes of the positive steam void coefficient and the negative Doppler coefficient of reactivity. Two models are considered, according to the types of instability to be prevented.

The first one assumes Newtons law of cooling with coupled heat transfer, but neglects the influence of those parts of the closed steam loop which are outside the reactor core. From a theorem by Popov necessary and sufficient conditions for asymptotic stability in the large are obtained. These conditions state that

a) the equilibrium net power coefficient must be negative,

b) a power pulse must result in an initial drop in reactivity,

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c) redistribution of heat following the power pulse must not cause any further decrease of reactivity.

According to the inherent limitations of the first model the satisfaction of these conditions is considered to ensure against selfsustained oscillations with periods comparable to or shorter than the coolant transit time through the core.

The second model of reactivity feedback is more realistic if possible instabilities at intermediate and lower frequencies are to be considered. Heat transfer from the fuel element to dry steam as well as the performance of out of pile parts of the coolant loop are described in a rather general and flexible manner by a series of characteristic parameters, valid at least in the neighbourhood of the considered equilibrium state. Applying the First Stability Theorem by H.B. Smets, a necessary condition for the asymptotic stability in the large is derived for such a system with linear reactivity feedback. Using some approximations well justified in the light of published design characteristics of a 300 MW_e steam cooled fast breeder reactor power plant, a simplified version of the former criterion is found: the ratio of the Doppler coefficient to the steam void coefficient is greater or equal to an elementary expression containing only two essential characteristics, which are an average relaxation time for heat removal from the fuel and a suitable parameter which characterizes the efficiency of heat removal from the primary steam loop.